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STUDY OF 25 KHz CHANNEL SPACING IMPLEMENTATION IN THE VHF AIR TRAFFIC CONTROL COMMUNICATIONS BAND FOR LOW ALTITUDE EN ROUTE AND TERMINAL FACILITIES.

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16. Abstract
The FAA Spectrum Management Branch is responsible for making long range plans for the use of frequencies in the VHF air traffic control communications band (118 - 136 MHz). In February 1972 the decision was made to split channels in this band from 50 kHz to 25 kHz channel spacing. Plans were initially made to implement reduced channel spacing only in the high altitude en route sectors. The first of these assignments was made in June 1977. The purpose of the studies contained in this report was to form the basis of an implementation schedule for low altitude en route and terminal facilities. The effects of the newly proposed Terminal Control Areas as well as the effects of the expected growth in the number of new frequency assignments were studied and results indicated that 25 kHz channel spacing should be implemented in low altitude en route and terminal sectors in 1982 and 1984 respectively.

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METRIC CONVERSION FACTORS

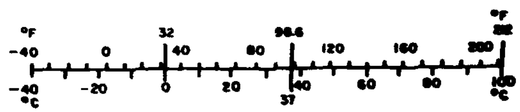
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10.286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT BRANCH

STATEMENT OF MISSION

The mission of the Spectrum Management Branch is to assist the Department of State, National Telecommunications and Information Administration, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world and to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radiofrequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio frequency spectrum to support the aeronautical interest of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, and standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/intersystem viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

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1. GENERAL

The purpose of the following studies was to evaluate the impact of new Terminal Control Areas and the expected growth in the number of frequency requirements on the implementation of 25 kHz channel spacing in the VHF air traffic control (ATC) communications band (118-136 MHz). The studies were performed by the Federal Aviation Administration (FAA) Spectrum Management Branch in cooperation with the Electromagnetic Compatibility Analysis Center (ECAC) using computer models developed and operated for the FAA by ECAC personnel.

2. BACKGROUND

a. In the early 1970's, several studies were performed which indicated that the number of frequencies available for ATC communications was insufficient to satisfy all of the anticipated frequency requirements within the constraints of the assignment criteria. Of the solutions proposed, a change from 50 kHz to 25 kHz channel spacing was determined to be the most advantageous course of action.

b. Public notice of FAA's intention to channel split was made in a "Notice of Invitation for Comments" published in the Federal Register on February 2, 1972. The following implementation schedule for 25 kHz channel spacing was proposed:

January 1976 - Introduced into selected high altitude en route sectors.

June 1976 - Deployment at high altitude en route sectors. Introduction into selected high density low altitude en route sectors.

June 1977 - Deployment at low altitude en route sectors.

June 1979 - Deployment at selected air traffic control tower facilities and selected flight service stations.

Comments received from the aviation community indicated agreement with the need to channel split, but that the proposed schedule was too ambitious for many of the users to meet. Based on these comments and the unexpected decline in the growth rate of aviation during the Arab oil embargo, the proposed schedule was revised. In the Federal Register dated May 21, 1973, the FAA gave notice that implementation of 25 kHz channel spacing would begin in the high altitude en route sectors in January 1977. The schedule to implement 25 kHz channel spacing in the low altitude en route and terminal sectors was not defined pending further study by the FAA.

c. Between 1973 and 1976, the FAA undertook an equipment replacement program to prepare existing RCAG sites for 25 kHz channel spacing to be implemented beginning in 1977. The first 25 kHz assignments were made operational in June 1977. At present there are approximately forty 25 kHz assignments operational in the United States with additional 25 kHz assignments being made as needed. In some areas of the country, particularly the Great Lakes Region, it is nearly impossible to make a new frequency assignment, even on 25 kHz spaced channels, without shifting one or two existing assignments to other frequencies. As 25 kHz channel spacing is implemented in the high altitude en route sectors and as it becomes more difficult to make new frequency assignments, plans must be made to implement 25 kHz channel spacing in the low altitude en route and terminal sectors. The FAA has a commitment to publish a proposed schedule as soon as possible so the the aviation community may comment and have adequate time to prepare for the change.

3. DESCRIPTION OF THE ASSIGNMENT MODEL

To make long range frequency assignment plans, the FAA makes use of an automated frequency assignment model developed and operated for FAA by ECAC. With this assignment model, different assignment strategies can be simulated and the impact of each strategy on the spectrum available to ATC communications can be compared to determine the best course of action. This same model was used to plan 25 kHz implementation in the high altitude en route sectors. Since then the model has been modified and expanded to run more efficiently and to provide the user more flexibility.

a. Assignment Criteria

(1) The frequency assignment model bases its calculations on standard FAA assignment criteria. Cochannel assignments must be afforded a 14 dB signal ratio at the victim aircraft receiver between the desired ground-to-air signal and the undesired air-to-air signal from an aircraft in another service volume. The service volumes of adjacent channel assignments (frequencies offset by one channel width for assignments with like channel spacing) must be separated by a least 2 nmi. (3.7 km). Since there is a mixture of 50 kHz and 25 kHz equipment in the environment during the transition to 25 kHz channel spacing, 50 kHz receivers must be protected from interfering transmissions offset by 25 kHz (25 kHz interleaving). The FAA assumes that a receiver designed for 50 kHz channel spacing will provide 6 dB of rejection to a signal offset by 25 kHz. Therefore, assignments offset by 25 kHz are afforded 8 dB of protection by geographic separation. This 8 dB plus the 6 dB obtained from the receiver rejection is equivalent to the 14 dB obtained in the cochannel case. Together, these three analyses are referred to as the intersite analysis.

(2) Interference interactions between facilities located at or near the same site are as much of a problem as the cochannel and adjacent channel interference discussed above. ATC communications channels located at the same site must be separated by at least 500 kHz. For the computer model, the site is defined as having a radius of .2 nmi (.4 km). To avoid intermodulation interference, all two signal third order intermodulation products of nearby FM, TV, and VHF communications/navigation frequencies are calculated. Any ATC communications frequency which coincides with an intermodulation product will not be considered for assignment at the site. To avoid harmonic interference, the second and third order harmonics of FM and TV frequencies in the area plus the second and third subharmonics of local UHF ATC communications frequencies are calculated. Again if a harmonic or subharmonic coincides with an ATC communications frequency, that frequency is not considered for assignment. For the computer calculation, FM and TV channels within 15 nmi (27.6 km) and ATC communications/ navigation stations within ½ nmi (.9 km) of the site are considered in the intermodulation and harmonic analyses. Together, the adjacent signal, intermodulation, and harmonic analyses form the cosite analysis. The intersite and cosite assignment criteria remain constant for all studies except for those designed to test the effect of a change in criteria.

b. Assignment Data Base

The intersite and cosite analyses require an extensive data base. Two data files, the requirements file for the intersite analysis and the background file for the cosite analysis, were developed by drawing information from a wide range of sources. The requirements file contains the existing VHF A/G communications assignments in the ATC portion of the 118-136 MHz band for the continental United States, Canada, and Mexico. Sources for this information are:

The Continential U.S. -- IRAC Government Master File
Canada -- Date tape supplied by the Canadian Government
Mexico -- ICAO CARSAM Frequency Listings

En route frequency records contain the coordinates of the associated multipoint tailored service volume. This information is extracted from the FAA's Adaptation Controlled Environment System (ACES) tapes supplied by each ATC center. The background file contains all the FM, TV, and VHF/ UHF communications/navigation frequencies in the continental U.S. required for the cosite analysis.

Sources for this file are:

VHF/UHF Com/Nav, 108-136 MHz -- IRAC Government Master File
225-400 MHz

FM & TV, 54-108 & 174-216 MHz -- Data tape supplied by the FCC

VHF Operational Control, 128.8-132.0 MHz -- ARINC data tape

Different assignment strategies can be simulated by manipulating the data base, the available frequencies, the allowable channel spacing, and the order of assignment. The impact of different strategies can then be compared to determine the most advantageous assignment plan. By adding a list of future frequency requirements to the data base, the impact of expected requirements can be assessed and a schedule for making a particular change in criteria such as reduced channel spacing can be developed.

4. ANALYSIS OF THE PRESENT ENVIRONMENT

a. Before trying to determine the impact of future frequency requirements, an analysis was made of the existing environment (as of January 1979). Three basic assignment strategies were tested:

1. All FAA frequency requirements were reassigned with only high altitude en route facilities eligible for 25 kHz spaced channels.

2. All FAA frequency requirements were reassigned with both high and low altitude en route facilities eligible for 25 kHz spaced channels.

3. All FAA frequency requirements were reassigned on 25 kHz spaced channels.

Each strategy was tested several times as cosite criteria, assignment order, and other parameters were varied.

b. Results indicate that even reassigning every frequency requirement using the most efficient assignment method available would not relieve the frequency congestion problem. A few existing requirements in major terminal areas such as New York and Chicago could not be satisfied when only high altitude en route requirements were eligible for 25 kHz spaced channels (strategy 1). The cosite criteria had to be modified to account for the use of additional RF filtering and separate transmitter and receiver sites before frequencies could be found for these requirements. Adding low altitude en route requirements to those eligible for 25 kHz spaced channels (strategy 2) resulted in more requirements being assigned using the standard criteria, however this strategy still required the use of modified cosite criteria in some geographic areas. Strategies 1 and 2 both required the entire ATC spectrum to assign a frequency to every requirements. Only when every requirement was eligible for 25 kHz spaced channels (strategy 3) did any spectrum remain unused. These results indicate that there is little if any reserve capacity for future requirements if only high altitude en route requirements are eligible for 25 kHz spaced channels. In some areas of high frequency congestion such as Chicago, this reserve is already being exhausted. The following studies will estimate when the reserve capacity will run out completely by adding frequency requirements for future facilities to the environment.

5. EFFECTS OF THE PROPOSED NEW TERMINAL CONTROL AREAS

On December 27, 1978, FAA Administrator, Langhorne Bond, issued the "Plan for Enhanced Safety of Flight Operations in the National Airspace System." Among other steps proposed, it was decided to establish 41 new Terminal Control Areas (TCA's). To upgrade many of these existing terminal areas to TCA's could require new frequencies and/or extended service volume radii and altitudes on existing facilities. These changes could have a major effect on the schedule for implementation of 25 kHz channel spacing in the low en route and terminal sectors.

a. New TCA Requirements

(1) The existing and proposed TCA locations are listed in Appendix A, grouped into implementation phases. Of the TCA's originally proposed by the Administrator, those for San Juan, Puerto Rico, Kahului, Hawaii, and Anchorage, Alaska were not considered in this study because they would not effect frequency congestion in the contiguous United States. In addition, on September 7, 1979, six of the proposed TCA's (Des Moines, Iowa, El Paso, Texas, Jacksonville, Florida, Lihue, Hawaii, Salt Lake City, Utah, and Tucson, Arizona) were withdrawn. Therefore, these were also dropped from this study. Three additional locations, (Honolulu, Hawaii, Tampa, Florida, and Pheonix, Arizona) were already in the process of being upgraded to TCA status before the Administrator's order; therefore changes to the frequency requirements for these sites were assumed to be complete. The remaining 32 locations were used to generate the future frequency environment. Originally proposed TCA's which were not used in the study are marked with a star in Appendix A.

(2) Based on a study of existing TCA locations, the following frequency requirements were found to be common to all TCA's. Therefore, each new TCA should have as a minimum:

1. One (1) ground control channel with a service volume range of 2 nmi (3.7 km) at an altitude of 100 feet (30 m).

2. One (1) ATIS channel with an extended service volume range of 60 nmi (111 km) at 20,000 feet (6000 m).

3. At least one (1) approach control channel and one (1) departure control channel each with an extended service volume range of 60 nmi (111 km) at 20,000 feet (6000 m).

4. A minimum of two (2) local control channels (one for local control, one for clearance delivery each with a service volume range of 30 nmi (55 km) at 10,000 feet (3000 m).

(3) Each of the 32 proposed TCA'S of interest were examined. New frequency requirements were added or existing requirements were extended in range if the above minimum was not existing at the location. Appendix A contains a list of the proposed TCA locations, the geographic coordinates assumed for their communication outlets, and the frequency changes which were necessary. The frequency assignment model was then used to assign the TCA frequency requirements which resulted from additions or changes to the existing frequencies for the location.

b. TCA Assignments Performed

Assignment of the projected TCA frequency requirements was made by year according to the Administrator's implementation schedule. Three different assignment strategies were used in which all new TCA frequency requirements were assigned with the high altitude en route requirements handled differently each time.

1. The high altitude en route requirements could not be reassigned (ie. fixed in frequency). This would be a very restrictive approach.

2. All high altitude en route requirements were reassigned on any available frequency. This simulates the present procedure of reassigning high en route requirements to accommodate a new terminal assignment.

3. All high altitude en route requirements were forced on to the odd 25 kHz frequencies (ie. the odd multiples of 25 kHz, such as 118.025, 118.125, etc.). This simulates the effect of one proposed change in assignment procedures.

All other existing requirements (low altitude en route and terminal) were fixed in frequency for each assignment strategy. The standard criteria for cochannel, adjacent channel 25 kHz interleaving, and cosite interference protection were used in each assignment. Assignments for terminal requirements were made starting with the lowest possible frequency (118.0 MHz) and working up while assignments for en route requirements were made using first the highest possible frequency (135.975 MHz) and working down.

c. Results of the TCA Assignment Study

Figure 1 is a tabulation of the assignment studies performed and the results. In each assignment, all high altitude en route requirements were reassigned without difficulty, therefore only the number of new TCA requirements which could not be assigned are listed in the table.

FIGURE 1

Assignment Studies for Future TCA's

	# TCA Requirements to Assign	# of New TCA Requirements Not Assigned		
		Assignment I High's Fixed	Assignment II High's on any 25 kHz Freq	Assignment III High's on odd 25 kHz Freq
Phase I (complete end 1980)	32	3	1	0
Phase II (complete end 1981)	68	29	24	1
Phase II (complete end 1983)	17	10	5	1

Assignment II in the table reflects the existing assignment policy. It is apparent that by the end of 1981 under the existing policy, a serious problem could exist in trying to accommodate changes and additions required to implement new TCA's even if no other future frequency requirements were established. Assignment III indicates that all but two of the expected TCA changes could be assigned if all high altitude en route requirements were shifted to odd 25 kHz channels. While it would not be practical to physically reassign all existing high altitude en route requirements, Assignment III does give an indication of the benefits such a change in assignment procedures would have. If as many high altitude en route requirements as possible were shifted to odd 25 kHz channels over the next few years, the effect of establishing the new TCA's could be minimized.

6. ANALYSIS OF FUTURE REQUIREMENTS

The analysis of the proposed TCA's shows only the effects of the proposed TCA's and not the frequency requirements which result from normal growth. A separate analysis of other future requirements was also performed to show the effects of normal growth. The list of changes and additions to the frequency requirements at the proposed TCA's was not used in this study so that the effects of normal growth could be examined separately. However, the existing and proposed TCA's were used to identify the locations of major airports where the noraml growth in the number of requirements could have a significant impact on frequency congestion.

a. Number of Requirements

To estimate the number of expected new frequency requirements each year, a growth rate was determined by linearly extrapolating the growth in requirements from 1973 to 1979 on through 1985. A rate of growth in new requirements of 4% per year was obtained. This figure correlates very well with the actual and projected growth in IFR traffic over the same period. From 1973 to 1979, the ratio of the number of high altitude en route to low altitude en route to terminal assignments remained essentially constant. Therefore, the 4% per year growth rate can be applied to each type of facility without weighting one type over the others. Figure 2 is a list of the total number of frequency requirements expected each year through 1985.

FIGURE 2

Total Number of VHF ATC Frequency Requirements Expected Each Year Through 1985

Year	High Altitude En Route Requirements	Low Altitude En Route Requirements	Terminal Requirements
1979*	475	612	2049
1980	494	636	2131
1981	514	661	2216
1982	535	687	2305
1983	556	714	2397
1984	578	743	2493
1985	601	773	2593

*From ECAC data based requirements file as of January 1979

b. Location of Future Requirements

To accurately predict the impact of future frequency requirements, their geographic locations are as important as their number. New en route requirements are usually established to fill holes in coverage and to cover new sectors created when old sectors become too heavily congested with air traffic. Coverage gaps and sector changes occur randomly across the country. Therefore, the geographic coordinates for future en route requirements were generated at random. Appendix B contains list of 60 new RCAG sites generated at random to accommodate the future en route requirements. Figure 3 is a map showing these locations. New terminal requirements result when new air traffic control towers (ATCT's) are established or when new services are offered at small airports. New terminal requirements would also be established at major airports to relieve congestion on existing frequencies. To simulate the creation of new ATCT's and services, some of the terminal locations were generated at random. It was assumed that each of these new sites would require 2 frequencies. To simulate new requirements being added at major airports, it was assumed that at least one new frequency per year will be required at each of the 60 existing and proposed TCA locations. Appendix B also contains a list of the geographic locations of the 60 TCA sites and 92 sites generated for new ATCT's and new services. Figures 4 and 5 are maps showing the locations of the TCA's and the randomly selected future terminal sites.

c. Service Volume Dimensions

Service volume radius and altitude are also important parameters in the assignment process. To simplify the generation of the future frequency environment, all new requirements were assumed to have circular service volumes with the following radii and altitudes:

1. High Altitude En Route	45,000 feet (13500 m) at 100 nmi (184 km)
2. Low Altitude En Route	18,000 feet (5400 m) at 60 nmi (111 km)
3. Terminals	12,500 feet (3750 m) at 30 nmi (55 km)

Service volumes #1 and #2 are of standard dimensions listed in existing FAA frequency assignment documents. Service volume #3 is an average of the standard dimensions listed for all the various types of standard terminal facilities.

d. Future Requirements Assignment Study

The future requirements generated above were added to the data base so that they would be assigned frequencies sequentially by year. All existing terminal requirements were fixed in frequency and the following strategies used to assign the future terminal, existing en route, and future en route requirements:

FIGURE 3
Location of Future RCAG Sites

FIGURE 4
Location of Existing and Future TCA's

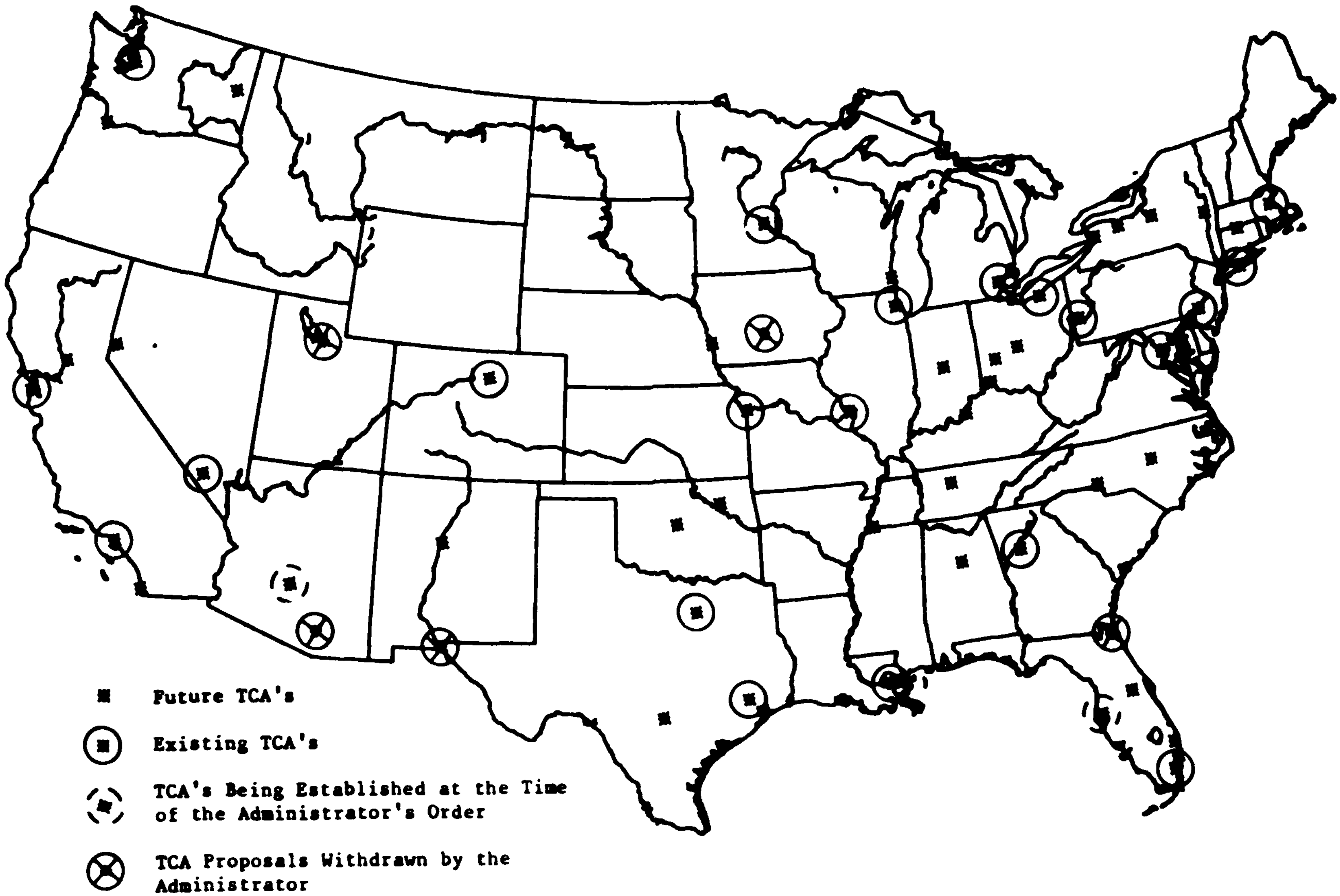
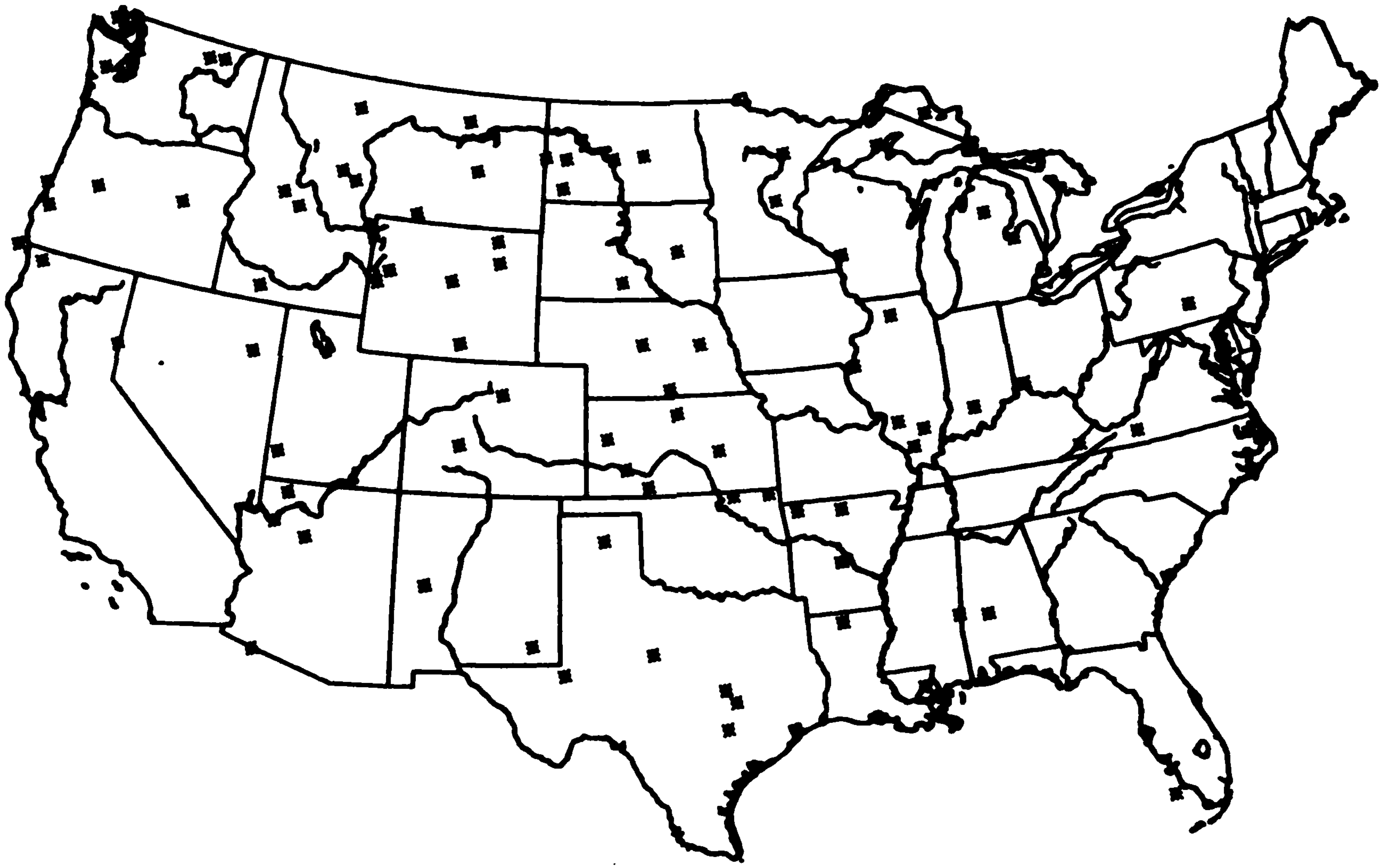


FIGURE 5
Location of Future ATC
Terminal Facilities



1. Future terminal requirements were assigned on any 50 kHz spaced frequency; existing low altitude en route requirements were fixed in frequency; future low altitude en route requirements were assigned on any 50 kHz spaced frequency; and all existing and future high altitude en route requirements were assigned on any 25 kHz spaced frequency. This assignment simulates the existing procedure where high altitude en route requirements are shifted to 25 kHz spaced channels to accommodate a new terminal requirement.

2. Future terminal requirements were assigned on any 50 kHz spaced frequency; all existing and future en route requirements were assigned on any 25 kHz spaced frequency. This assignment simulates how the present assignment procedure would probably be extended when low altitude en route facilities were made eligible for 25 kHz spaced frequencies.

3. This assignment was the same as Number 1 except that all existing and future high altitude en route requirements were forced on to odd 25 kHz frequencies.

4. This assignment was the same as Number 2 except that all existing and future en route requirements were forced on to odd 25 kHz frequencies.

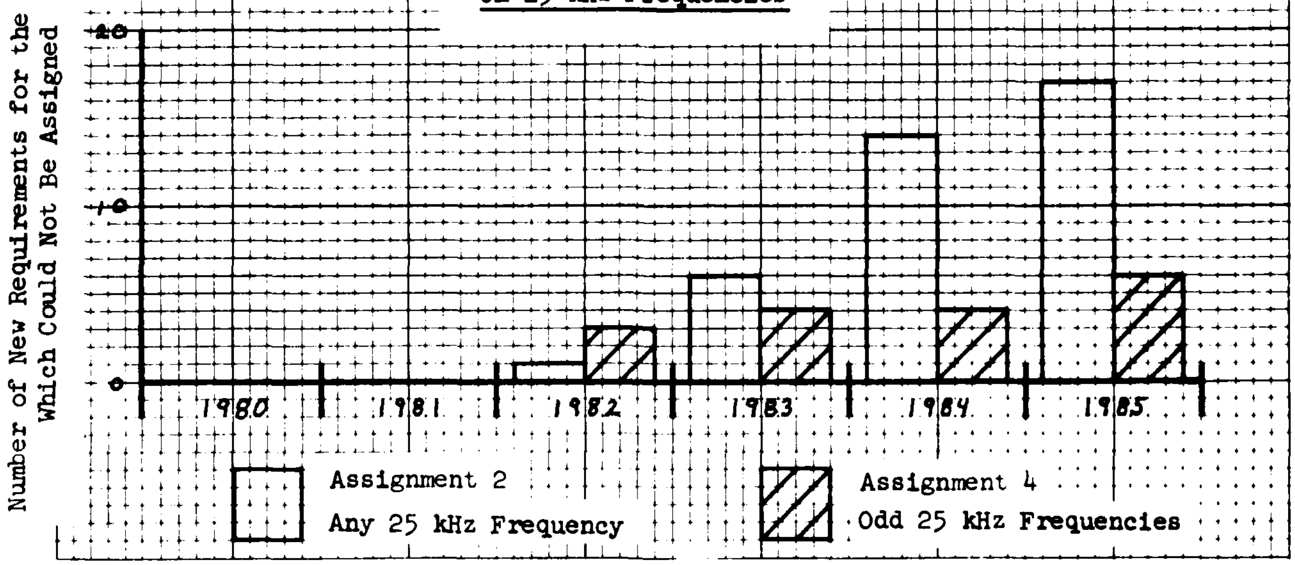
Again, the standard intersite and cosite interference protection criteria were used to assign terminal requirements on the lowest possible interference free frequency and en route requirements on the highest.

e. <u>Results of the Future Requirements Assignment Study</u>

Figures 6 and 7 are bar charts illustrating the number of requirements for which assignments could not be made each year from the end of 1980 through the end of 1985. Figure 6 is a comparison of Assignments 1 and 3 while Figure 7 compares Assignments 2 and 4. An examination of Assignment 1 in Figure 6 shows that by the end of 1981, all anticipated requirements cannot be assigned if only high altitide en route requirements are eligible for 25 kHz spaced channels. Therefore, beginning in 1982, 25 kHz assignments should be made for low altitude en route requirements. An examination of Assignment 2 in Figure 7 shows that by the end of 1983, all anticipated frequency requirements cannot be assigned if only en route requirements are eligible for 25 kHz spaced channels. Therefore beginning in 1984, 25 kHz assignments should be made for terminal requirements. Assignments 3 and 4 in Figures 6 and 7 respectively, illustrate the benefit of forcing requirements which are eligible (this includes low altitude en routes after 1982) on to the odd 25 kHz frequencies.

FIGURE 6
Study Results With
High Altitude En Routes
On 25 kHz Frequencies

FIGURE 7
Study Results With
All En Routes
On 25 kHz Frequencies



7. CONCLUSIONS

a. The studies performed above were idealized examinations of possible future environments. There were several possible variables which could not be accounted for. For example, frequency requirements resulting from other proposed new services such as positive control of helicopter operations, automatic weather broadcasts, and Automatic Terminal Systems could not be predicted and may or may not be accounted for in normal growth. Other factors which affect the number of requirements which can be assigned (such as increases in the number of FM and TV broadcast stations and in the number of Canadian and Mexican assignments) were not included because information on projected growth in the number of these facilities was not available.

b. The studies which were performed for future environments indicated that a change to 25 kHz channel spacing for low altitude en route requirements was necessary beginning in 1982. The future requirement studies indicated that a further change to 25 kHz channel spacing for terminal requirements would be necessary beginning in 1984. This study also indicated the benefit of forcing all facilities eligible for 25 kHz spaced channels (including low en route facilities after 1982) on to the odd 25 kHz frequencies. However, because of the impracticality of reassigning every en route requirement and because of the unaccounted variables discussed above, the years 1982 and 1984 should be milestones for further implementation of 25 kHz channel spacing in low altitude en route and terminal assignments respectively.

8. RECOMMENDATIONS

a. Public Notice of FAA's intention to further implement 25 kHz channel spacing in low altitude en route and terminal sectors starting in January 1982 and January 1984 respectively, should be made as soon as possible. Public comments should be invited.

b. Maximum use of the odd 25 kHz frequencies should be made when and where possible.

c. An equipment replacement program similar to that instituted for RCAG sites between 1973 and 1976 should be established as soon as possible to prepare terminal sectors for the change to 25 kHz channel spacing by 1984.

9. REFERENCES

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c. Department of Transportation, Federal Aviation Administration, Plan for Enhanced Safety of Flight Operations in the National Airspace System, December 27, 1978.

d. Department of Transportation, Federal Aviation Administration, "Proposed Integration of 25 kHz Spaced Channels into the National Airspace System: Notice of Invitation for Comments," Federal Register, Docket 72-1865, February 9, 1972.

e. Federal Aviation Agency, VHF/UHF Air/Ground Communications Frequency Engineering Handbook, Order 6050.4A, June 1965.

f. Hensler, Thomas, Automated VHF Frequency Assignment System (FAS) for FAA Air Traffic Control Communications, FAA-RD-76-14 and FAA-RD-76-14 Supp. 1, February 1976 and July 1978.

g. Hensler, Thomas, FAA VHF ATC Frequency Assignment Plans, ECAC-CR-79-015, January 1979.

H. Hensler, Thomas, FAA VHF Spectrum Utilization Study, ECAC-CR-80-008, February 1980.

i. IFR Aircraft Handled, FAA-AVP-76-13, November 1976.

j. U.S. Department of Transportation News, "FAA Drops Airspace Proposals," FAA-59-79, September 7, 1979.

APPENDIX A TERMINAL CONTROL AREAS

1. Existing TCA's

Atlanta, Georgia
Boston, Massachusetts
Chicago, Illinois
Dallas-Fort Worth, Texas
Los Angeles, California
Miami, Florida
New York (Kennedy, LaGuardia, Newark)
San Francisco, California
Washington, D. C.
Cleveland, Ohio
Denver, Colorado
Detroit, Michigan
Houston, Texas
Kansas City, Missouri
Las Vegas, Nevada
Minneapolis, Minnesota
New Orleans, Louisiana
Philadelphia, Pennsylvania
Seattle, Washington
St. Louis, Missouri
Pittsburgh, Pennsylvania

2. Proposed TCA's

a. Phase I

Memphis, Tennessee
Orlando Florida
Portland, Oregon
* Des Moines, Iowa
Spokane, Washington
Sacramento, California
Rochester, New York
* Jacksonville, Florida
Tulsa, Oklahoma
* El Paso, Texas
* Tucson, Arizona
* Salt Lake City, Utah
San Diego, California
Albuquerque, New Mexico
San Antonio, Texas
Albany, New York

b. Phase II

* San Juan, Puerto Rico
Fort Lauderdale, Florida
Buffalo, New York
Baltimore, Maryland
Cincinnati, Ohio
Charlotte, North Carolina
* Kahului, Hawaii
Nashville, Tennessee
Louisville, Kentucky
Oklahoma City, Oklahoma
Omaha, Nebraska
Windsor-Locks, Connecticut
Dulles, Virginia
Columbus, Ohio
Dayton, Ohio
Norfolk, Virginia
Syracuse, New York
Raleigh-Durham, North Carolina
Birmingham, Alabama

c. Phase III

Milwaukee, Wisconsin
* Lihue, Hawaii
Indianapolis, Indiana
* Anchorage, Alaska
West Palm Beach, Florida
Reno, Nevada

3. TCA's Presently Being Implemented

* Honolulu, Hawaii
* Tampa, Florida
* Phoenix, Arizona

4. Changes Made to Data Base for TCA Assignment Study.

a. Phase I

City	Lat/Long. (deg,min,sec) for additions	Changes or Addtions to Data Base: Func.	IRAC ID	New Service Volume: Radius (NMI)	Height (fee
Memphis, TN	35 03 52	ATIS	702417	60	20,000
	89 58 57	App	691219	60	20,000
		Dep	723473	60	20,000
Orlando, FL	28 33 09	ATIS	732637	60	20,000
	81 20 21	Dep	712014	60	20,000
		App	702513	60	20,000
		Grd Con	added	2	100
Portland, OR	45 35 50	ATIS	added	60	20,000
	122 36 34				
Spokane, WA	47 40 50	ATIS	741617	60	20,000
	117 19 08	Grd Con	added	2	100
	or	Dep	added	60	20,000
	47 37 14				
	117 39 17				
Sacramento, CA	38 41 59	ATIS	772522	60	20,000
	121 35 33	App	672036	60	20,000
	or	Dep	added site 2	60	20,000
	38 40 20	Loc Con	added site 1	30	10,000
	121 24 37				
Rochester, NY	43 07 35	App	700884	60	20,000
	77 40 01	Dep	693259	60	20,000
	or	ATIS	added	60	20,000
	43 07 01	Loc Con	added	30	10,000
	77 40 01				
Tulsa, OK	36 11 56	App	756469	60	20,000
	95 53 10	Dep	722068	60	20,000
		Loc Con	691167	30	10,000
San Diego, CA	32 41 00	ATIS	724234	60	20,000
	117 14 00	App	770150	60	20,000
		Dep	added	60	20,000
Albuquerque,NM		ATIS	741629	60	20,000
		App	756322	60	20,000
San Antonio, Tx		ATIS	757188	60	20,000
Albany, NY	42 44 40	ATIS	733214	60	20,000
	73 49 20	App	723439	60	20,000
		App	682988	60	20,000
		Loc Con	added	30	10,000

b. Phase II

City	Lat/Long (deg,min,sec) for additions	Changes or Additions to Data Base Func.	IRAC ID	New Service Volume Radius (nmi)	Height (feet)
Ft. Lauderdale FL.	26 04 28	App	691916	60	20,000
	80 09 01	Dep	713700	60	20,000
		ATIS	added	60	20,000
Buffalo, NY	42 56 11	App	741615	60	20,000
	78 44 39	Dep	741616	60	20,000
		ATIS	added	60	20,000
Baltimore, MD	39 11 04	App	711867	60	20,000
	76 40 33	ATIS	added	60	20,000
		Dep	added	60	20,000
Cincinnati, OH	39 02 36	Dep	752266	60	20,000
	84 39 52	App	added	60	20,000
		ATIS	added	60	20,000
Charlotte, NC	35 12 38	App	773962	60	20,000
	80 56 12	Dep	691758	60	20,000
		Loc Con	774055	30	10,000
		ATIS	added	60	20,000
Nashville, TN	36 08 05	ATIS	712621	60	20,000
	86 41 30	App	691439	60	20,000
		Dep	723042	60	20,000
Louisville, KY	38 13 39	ATIS	712003	60	20,000
	85 39 39	Dep	680810	60	20,000
	or	App	720780	60	20,000
	38 11 16				
	85 44 08				
Oklahoma City OK	four sites	ATIS	756698	60	20,000
	see IRAC ID	Loc Con	757184	30	10,000
	records	Loc Con	757194	30	10,000
		App	756843	60	20,000
		Dep	756501	60	20,000
Omaha, NB	41 18 38	ATIS	672518	60	20,000
	95 54 28	App	773651	60	20,000
	or	App	773984	60	20,000
	41 07 23	Loc Con	744318	30	10,000
	95 55 03				
Windsor-Locks CN	41 56 22	Loc Con	711096	30	10,000
	72 40 31	App	724252	60	20,000
		App	724251	60	20,000
		ATIS	added	60	20,000
		Loc Con	added	30	10,000

Columbus, OH	39 59 59	ATIS	713721	60	20,000
	82 53 44	Dep	681407	60	20,000
		App	744445	60	20,000
Dayton, OH	39 54 10	ATIS	757692	60	20,000
	84 13 03	Dep	681406	60	20,000
		App	711006	60	20,000
		Loc Con	added	30	10,000
		Grd Con	added	2	100
Dulles, VA	38 56 31	ATIS	732742	60	20,000
	77 25 42	App	713669	60	20,000
		App	713665	60	20,000
		Loc Con	711089	30	10,000
		Loc Con	added	30	10,000
Norfolk, VA	36 53 27	ATIS	732585	60	20,000
	76 12 25	App	691850	60	20,000
		Dep	691849	60	20,000
		Loc Con	691193	30	10,000
		Loc Con	682542	30	10,000
Syracuse, NY	43 06 35	App	711730	60	20,000
	76 05 51	App	682110	60	20,000
		ATIS	added	60	20,000
		Loc Con	added	30	10,000
Raleigh-Durham	35 52 01	ATIS	723058	60	20,000
NC	78 47 01	App	723043	60	20,000
		App	774654	60	20,000
		Loc Con	691252	30	10,000
		Loc Con	added	30	10,000
Birmingham, AL	33 34 27	ATIS	681388	60	20,000
	86 45 12	App	760900	60	20,000
		Dep	711737	60	20,000
		Loc Con	691304	30	10,000
		Loc Con	766934	30	10,000

c. Phase III

City	Lat/Long. (deg,min.sec) for additions	Changes or Additions to Data Base			
		Func.	IRAC ID	New Service Volume	
				Radius (nmi)	Height (feet)
Milwaukee, WI	42 57 00	ATIS	759081	60	20,000
	87 54 03	Dep	720769	60	20,000
		App	691747	60	20,000
Indianapolis IN	39 43 44	ATIS	672479	60	20,000
	86 17 53	Dep	713454	60	20,000
		App	756832	60	20,000
West Palm Beach FL.	26 41 12	ATIS	732867	60	20,000
	80 06 14	App	740984	60	20,000
		Dep	696145	60	20,000
		Loc Con	691206	30	10,000
		Loc Con	696146	30	10,000
		Grd Con	added	2	100
Reno, NV	39 31 53	ATIS	741958	60	20,000
	119 39 18	App	753700	60	20,000
		Loc Con	713938	30	10,000
		Loc Con	743842	30	10,000
		Dep	added	60	20,000

APPENDIX B FUTURE FREQUENCY REQUIREMENT LOCATIONS

1. Major Terminal Areas

Site #	City/State	Latitude	Longitude	New Site
T1	Atlanta, Ga	33 39 28	84 25 33	
T2	Boston, Mass.	42 21 55	71 01 06	
		42 27 06	71 02 12	
T3	Chicago, Ill.	42 00 19	87 54 47	
T4	Dallas-Ft Worth,Tex.	32 49 51	97 03 57	
T5	Los Angeles, Cal.	33 57 44	118 22 38	
T6	Miama, Fla.	25 48 09	80 21 07	
T7	New York, NY.	40 48 28	73 05 57	
T8	San Francisco, Cal.	37 37 14	122 21 52	
T9	Washington, D. C.	38 54 04	77 13 49	
T10	Cleveland, Ohio	41 30 55	81 40 55	
T11	Denver, Colo.	40 11 00	105 08 00	
T12	Detroit, Mich.	42 13 25	83 21 32	
T13	Houston, Tex.	29 58 44	95 19 55	
T14	Kansas City, Kans.	39 08 37	94 36 34	
T15	Las Vegas, Nev.	36 18 00	115 40 00	
T16	Minneapolis, Minn.	45 03 37	93 20 39	
T17	New Orleans, La.	30 02 35	90 01 33	
T18	Philadelphia, Pa.	39 52 33	75 14 41	
T19	Pittsburgh, Pa.	40 32 07	80 13 08	X
T20	Seattle, Wash.	47 31 45	122 18 10	
T21	St. Louis, Mo.	38 48 52	90 23 09	
T22	Memphis, Tenn.	35 03 01	89 59 01	
T23	Orlando, Fla.	28 32 42	81 20 29	
T24	Portland, Ore.	45 35 21	122 35 32	
T25	Des Moines, Ia.	41 32 30	93 40 23	
T26	Spokane, Wash.	47 37 14	117 39 17	
T27	Sacramento, Cal.	38 40 20	121 24 37	
T28	Rochester, NY.	43 07 01	77 40 01	
T29	Jacksonville, Fla.	30 28 32	81 39 10	
T30	Tulsa, Okla.	36 13 56	95 54 10	X
T31	El Paso, Tex.	31 52 00	106 29 30	
T32	Tucson, Ariz.	32 06 46	110 57 18	
T33	Salt Lake City, Ut.	40 46 43	111 57 21	
T34	San Diego, Cal.	32 44 10	117 11 20	
T35	Albuquerque, NMex.	35 00 04	106 36 13	
T36	San Antonio, Tex.	29 32 18	98 28 01	
T37	Albany, NY.	42 46 40	73 50 20	X
T38	Ft. Lauderdale, Fla.	26 11 45	80 09 45	
T39	Buffalo, NY.	42 58 11	78 45 39	
T40	Baltimore, Md.	39 10 14	76 40 22	

Site #	City/State	Latitude	Longitude	New Site
T41	Cincinnati, Ohio	39 06 30	84 25 28	
T42	Charlotte, NCar.	35 14 38	80 57 12	
T43	Nashville, Tenn.	36 08 01	86 41 01	
T44	Louisville, Ky.	38 13 39	85 39 39	
T45	Oklahoma City, Okla.	35 37 10	97 38 24	
T46	Omaha, Neb.	41 18 38	95 54 28	
T47	Windsor-Locks, Conn.	41 58 22	72 41 31	X
T48	Dulles, Vir.	38 58 31	77 26 42	X
T49	Columbus, Ohio	40 04 30	83 04 15	
T50	Dayton, Ohio	39 48 22	84 05 52	
T51	Norfolk, Vir.	36 56 21	76 17 43	
T52	Syracuse, NY.	43 08 35	76 06 51	X
T53	Raleigh-Durham, NCar.	35 38 01	78 40 30	
T54	Birmingham, Ala.	33 33 57	86 45 04	
T55	Milwaukee, Wis.	42 55 38	87 53 53	
T56	Indianapolis, Ind.	39 49 47	86 17 41	
T57	West Palm Beach, Fla.	26 40 43	80 10 55	
T58	Reno, Nev.	39 29 38	119 45 59	
T59	Tampa, Fla.	27 59 51	82 32 35	X
T60	Phoenix, Ariz.	33 25 40	112 01 13	

2. Locations of New Air Traffic Control Towers or New Services

Site #	Latitude	Longitude
1.	43 06 11	110 40 55
2.	37 48 43	89 10 45
3.	38 37 42	89 39 49
4.	42 34 14	79 40 34
5.	35 50 53	113 28 00
6.	41 37 15	99 42 06
7.	40 29 07	91 08 46
8.	32 28 37	88 28 38
9.	48 09 05	107 30 09
10.	46 20 57	103 09 29
11.	41 33 18	97 20 27
12.	41 56 30	124 35 20
13.	38 28 35	106 55 45
14.	37 17 18	99 38 02
15.	41 56 02	89 21 20
16.	37 00 15	80 26 37
17.	32 33 27	104 02 23
18.	41 30 13	107 05 58
19.	40 01 01	120 03 50
20.	47 21 14	123 32 58

Site #	Latitude	Longitude
21.	29 46 43	97 13 36
22.	30 35 01	96 51 34
23.	43 12 19	123 56 37
24.	43 47 56	124 17 21
25.	37 50 02	100 29 03
26.	42 28 36	115 15 46
27.	38 19 53	88 42 06
28.	47 14 01	88 54 31
29.	44 37 49	105 49 26
30.	47 16 22	93 13 00
31.	42 52 34	73 13 55
32.	45 57 38	112 08 45
33.	25 47 34	82 02 43
34.	43 21 28	107 37 04
35.	44 06 51	122 20 14
36.	35 28 15	112 18 50
37.	31 40 17	102 55 47
38.	36 41 38	113 04 24
39.	48 04 35	112 27 24
40.	44 19 38	118 57 17
41	46 40 59	106 58 34
42.	32 12 51	99 43 38
43.	36 58 33	82 46 06
44.	37 49 55	113 38 16
45.	47 14 49	103 59 29
46.	46 11 25	112 44 46
47.	38 16 35	96 50 53
48.	35 40 53	101 22 22
49.	34 18 41	107 55 45
50.	39 10 41	84 25 17
51.	43 58 53	91 06 11
52.	30 58 48	97 12 48
53	44 37 13	84 40 28
54.	38 43 47	86 34 32
55.	44 35 22	106 13 05
56.	36 10 42	92 18 23
57.	39 27 40	98 24 27
58.	32 42 47	92 45 51
59.	47 23 48	99 34 50
60.	45 13 52	109 21 43

Site #	Latitude	Longitude
61.	36 51 33	96 25 06
62.	30 27 23	90 04 48
63.	44 23 31	111 02 13
64.	43 39 37	83 36 55
65.	40 35 04	115 04 59
66.	43 58 45	105 42 51
67.	48 34 20	118 46 55
68.	47 14 42	103 04 09
69.	40 01 26	105 18 55
70.	45 49 54	93 44 26
71.	36 14 45	93 59 49
72.	42 17 22	81 44 05
73.	38 46 33	101 11 01
74.	36 51 04	95 03 33
75.	43 31 54	100 29 55
76.	41 41 01	123 32 46
77.	32 09 46	113 45 54
78.	40 14 35	98 40 11
79.	47 17 00	100 55 59
80.	37 10 46	94 49 56
81.	44 25 50	98 08 57
82.	44 56 07	114 17 05
83.	32 21 31	87 25 29
84.	40 21 31	77 09 25
85.	34 34 06	92 32 27
86.	48 47 10	123 48 36
87.	48 29 16	119 27 11
88.	42 23 23	81 49 17
89.	41 35 25	123 24 07
90.	45 16 13	115 00 11
91.	43 28 35	110 14 03
92.	47 59 13	86 30 42

3. Location of Future RCAG Sites.

RCAG #	Latitude	Longitude
R 1.	38 17 49	118 49 38
R 2.	47 02 11	96 26 57
R 3.	40 21 55	94 42 37
R 4.	45 51 47	123 01 27
R 5.	44 18 25	92 43 02
R 6.	39 05 56	77 19 18
R 7.	30 31 02	101 49 51
R 8.	35 04 12	100 54 22
R 9.	44 06 37	110 44 31
R10.	44 44 52	85 27 24
R11.	29 39 48	104 44 38
R12.	34 23 12	86 29 55
R13.	47 35 25	116 37 53
R14.	47 20 41	123 56 27
R15.	29 43 58	95 55 29

RCAG #	Latitude	Longitude
R 16	42 46 46	70 37 12
R 17.	39 39 25	102 52 23
R 18.	35 48 43	106 17 59
R 19.	42 26 02	90 12 10
R 20.	35 44 01	93 33 02
R 21.	43 27 57	99 19 21
R 22.	40 46 16	77 17 37
R 23.	39 31 00	115 36 53
R 24.	44 21 21	75 14 17
R 25.	38 47 26	108 30 40
R 26.	36 49 07	75 52 27
R 27.	41 09 08	73 01 43
R 28.	39 21 09	121 18 48
R 29.	41 12 01	122 13 24
R 30.	35 08 28	99 54 48
R 31.	34 05 03	115 25 51
R 32.	33 07 28	87 21 42
R 33.	29 51 01	80 39 45
R 34.	43 39 22	106 04 08
R 35.	35 27 29	121 16 03
R 36.	26 15 57	99 09 40
R 37.	32 51 18	84 59 26
R 38.	45 57 40	87 46 27
R 39.	39 09 40	84 58 14
R 40.	38 53 36	89 54 32
R 41.	31 51 35	98 30 07
R 42.	45 16 13	115 00 11
R 43.	47 17 00	100 55 59
R 44.	40 14 35	98 40 11
R 45.	32 09 46	113 45 54
R 46.	36 51 04	95 03 33
R 47.	42 17 22	81 44 05
R 48.	43 58 45	105 42 51
R 49.	30 27 23	90 04 48
R 50.	36 51 33	96 25 06
R 51.	36 10 42	92 18 23
R 52.	30 58 48	97 12 48
R 53.	34 18 41	107 55 45
R 54.	46 11 25	112 44 46
R 55.	36 58 33	82 46 06
R 56.	46 40 59	106 58 34
R 57	44 56 18	69 32 24
R 58.	33 09 16	80 01 48
R 59.	34 20 02	118 05 56
R 60.	25 50 42	80 58 30

4. **Requirements Added to Data Base by Year.**

Year	Number of New Frequencies Per Site	Function	Site #	Total for Year
1980	2	High En Route	R1-R9	124
	1	High En Route	R10	
	2	Low En Route	R1-R12	
	1	Terminal	T1-T60	
	2	Terminal	1-11	
1981	2	High En Route	R11-R20	130
	1	Low En Route	R10	
	2	Low En Route	R13-R24	
	1	Terminal	T1-T60	
	2	Terminal	12-23	
	1	Terminal	24	
1982	2	High En Route	R21-R30	136
	1	High En Route	R31	
	2	Low En Route	R25-R37	
	1	Terminal	T1-T60	
	2	Terminal	25-38	
	1	Terminal	24	
1983	1	High En Route	R31	140
	2	High En Route	R32-R41	
	2	Low En Route	R38-R50	
	1	Low En Route	R51	
	1	Terminal	T1-T60	
	2	Terminal	39-54	
1984	2	High En Route	R42-R52	147
	1	Low En Route	R51	
	2	Low En Route	R52-R60	
	1	Low En Route	R1-R9	
	1	Low En Route	R10	
	1	Terminal	T1-T60	
	2	Terminal	55-72	
1985	2	High En Route	R53-R60	153
	2	High En Route	R12-R14	
	1	High En Route	R15	
	2	Low En Route	R16-R30	
	1	Terminal	T1-T60	
	2	Terminal	73-92	

APPENDIX C ACRONYMS

ACES	-	Adaption Controlled Environment System
ARINC	-	Aeronautical Radio Incorporated
ATC	-	air traffic control
ATCT	-	Air Traffic Control Tower
CARSAM	-	Caribbean and South American
dB	-	decibels
ECAC	-	Electromagnetic Compatibility Analysis Ceuter
FAA	-	Federal Aviation Administration
FCC	-	Federal Communications Commission
FM	-	frequency modulation
ICAO	-	International Civil Aviation Organization
IFR	-	Instrument Flight Rules
IRAC	-	Interdepartmental Radio Advisory Committee
kHz	-	kiloHertz
km	-	kilometer
m	-	meter
MHz	-	MegaHertz
nmi	-	nautical mile
RCAG	-	Remote Communications Air-Ground
TCA	-	Terminal Control Area
TSV	-	Tailored Service Volume
TV	-	television
UHF	-	Ultra High Frequency
VHF	-	Very High Frequency